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TALAR®— A Modular Step Scan Microwave Landing System

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Abstract

THE OPERATIONAL EXPERIENCE and recent evaluation data pertaining to the performance of TALAR, a step scanned microwave landing system is reviewed. The data reviewed covers a period of approximately 10 years. The basic functional operation of a step scan system is described, i.e., TALAR. A family of landing systems is then derived via modular interchange with the base line unit. Operational configurations such as short take off and landing, asynchronous split site, multi angle and multi channel are described.

Operational Background

The concept of a lightweight, portable microwave aircraft landing system was first investigated by Singer-General Precision, Inc. in 1961. It was further developed into a feasibility model under a U.S. Air Force contract in 1963. TALAR I was a mechanically scanned, Ku band system and as such was severely limited in coverage to course widths of ±0.5° in azimuth and elevation. The unit was also restricted in operational range largely because it used a simple video receiver.

To reduce the mechanical feed scan problems, a cassegrain fed, continuous conical scan system, TALAR II, was developed. This unit provided acceptable course guidance but retained the narrow coverage. Operational tests uncovered false courses in the region of ±5° from course line. Side lobe attenuation of 18 db was not sufficient to maintain an approach path free of bends and roughness in typical installations. The range problem was improved with the addition of a tunnel diode preamplifier. Range to 10 n.mi. in approximately ½″ rain per hour was achieved.

In an attempt to eliminate false course problems and at the same time extend the coverage, TALAR III, was equipped with separate, time duplexed, waveguide fed cover beams. This broadened system coverage to ±30° in azimuth. The guidance beam itself was changed to an elliptical pattern to provide asymmetric course widths (±2.5° azimuth, ±1° elevation). Installation flexibility was improved by separating the airborne equipment into two processing units, a co-located RF receiver antenna and an angle processor.

TALAR III and all its predecessors in much the same fashion as VOR compared the AM established by the beam scan motion to a spatially referenced FM signal impressed on the K band carrier. This technique did encounter signal fades and loss of the FM reference with resultant system transients (flag action) in certain coverage regions. Although many approaches were completed successfully, low approach tests over icy terrain (in arctic Sweden) indicated that TALAR III still had multipath contamination.

The interdependence created by a single rotating mechanical structure severely restricted satisfying the requirements of linear guidance within the course width, coverage over the total acquisition window, and freedom from multipath signals (side lobe rejection). A major revision to the

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concept of beam propagation was recognize as necessary and incorporated into TALAR IV. ldy

TALAR IV replaced the previous mechanical scanned antenna technique with four independent, electronically switched beams. Each is stepped with respect to time to provide azimuth and elevation course guidance along with integral spatial coverage. Independent antennas permitted pattern shaping sufficient to eliminate the multipath problems created by inadequate side lobe rejection. Improvements of 10 db in localizer and 12 db in glide slope were realized. The unit itself was mechanized into modules to provide flexibility and ease of service. The coverage limits became ±55° in azimuth 1° to 9° in elevation. The Air Force purchased and evaluated proto TALAR IV units in 1967. A large quantity (40 ground stations, 500 airborne units) of production units were deployed, starting in the Fall of 1970. The basic tactical step scan transmitting unit is shown in Fig. 1.

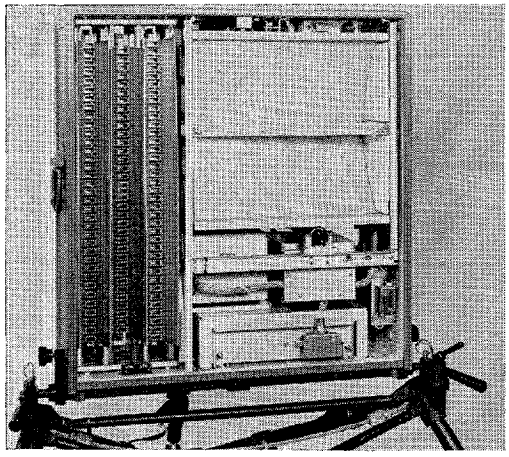

Fig. 1a—TALAR Ground Transmitter Front View.

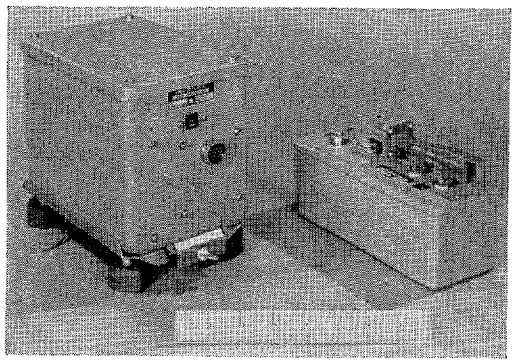

Fig. 1b—TALAR Airborne Equipment.

In conjunction with the above, tactical military activity, step scan production units have been part of numerous other civil and military evaluations. Table I below briefly summarizes these activities along with operational comments if relevant. It should be noted that the step scan system has been installed and flown in more than 25 types of aircraft ranging from the Convair 880 to the S61 and UH1.

Functional Description

TALAR is a one way step scan microwave landing guidance system operating in the Ku band (15.5 GHz nominal). In concept it is quite similar to VHF-UHF ILS and as such employs the identical display. It is a complete landing system in the sense it includes the basic ground guidance equipments, associated ancillary hardware and the airborne receiver/processor equipments. The system functions in the following manner. Microwave energy (10 watts average power) is generated within the ground station and directed via four independent ground antennas along the preplanned aircraft descent path to the airport runway. The antennas are paired in glide slope (elevation) and in localizer (azimuth). Each of the beam pairs straddle the desired approach path and are electronically switched or step scanned across the approach path according to Figures 2a and 2b at a rate of 134 cycles per second. Each single beam is, therefore, active for approximately $\frac{1}{134}$ second $\times \frac{1}{4}$ or 1.9 milliseconds. As each beam is energized during the scan cycle by the ground station, it is coded with an identifying, narrow band, subcarrier amplitude modulation. Typically, TALAR units use modulation frequencies of 191.2 and 192.8 KHz for the upper and lower elevation beams and 206.2 and 207.8 for the left and right localizer beams respectively. Since each beam (i.e., guidance signal) retains its own unique subcarrier modulation, each is, therefore, self encoded and can when received by appropriate airborne equipments be separated on a frequency basis independent of time of occurrence or sequence of occurrence. The flexibility afforded by self encoding permits the

Table I

Operation	User	No. of Approaches	Location	Comment
Tactical military evaluation March 1971	NATO	25	France	—Approaches made at various site types —2.5° to 6° G/S approaches were successfully flown —3.5° approaches were made with .5° obstruction clearance
STOL evaluation 2nd half 1970	FAA	Approx. 300 to 500	NAFEC	—Extensive Evaluation —6° to 9° G/S approaches flown —System was determined to be insensitive to pulse radar interference
Air carrier STOL evaluation June 1970 to present	Golden West Airlines	200	Calif.	—Minor environmental problems ground & airborne —System was exercised at 6° G/S —Pilot acceptance was established —Operations Spec Approval in process by FAA for GWA
Oct. 1970 to present	Houston Metro Airlines	150	Texas	—No operational problems —System exercised at 6° —Pilot acceptance established —In process OSA by FAA for HM
Oct. 1970 to present	Executive Airlines	150	Mass./Me.	—Installation power problems —Minor environmental problem —Operation at 4° —Evaluation limited
State California Dept. Aeronautics Gen. Av.—Evalution 3 months 1970	State Calif.	45	El Monte Torrence Fulleton	—Looked for difficult sites —Siting problems were not encountered
Vortex Study FAA June 1970		50	NAFEC	—Identified need to securely anchor units —Demonstrated ground units can be installed and flown in 5–10 min. Site insensitive

Table I *Continued*

Operation	User	No. of Approaches	Location	Comment
Tactical Landing Aids Evaluation	Alat (France)	150 (90 under hood)	Breigny (France)	—10 minute set up time verified —Used CTOL system to 7° G/S
Inter-City Metropolitan STOL evaluation March 1969 to May 1969	American Airlines	63	St. Louis Chicago New York	—System operated thru electrical transmission wires and in presence of large buildings adjacent to sites
Army Demos Sept. 1969	US Army	25	Fr. Rucker Alabama	—Installed UHl flew 3° to 6° G/S
Aug./Sept. 1970		30	Davison Air Field	—Installed and flown in UHl and U9 —Flew with DME capability
Split Site Performance Nov. 1970	FAA	6	NAFEC	—Performed asynchronous split site approaches

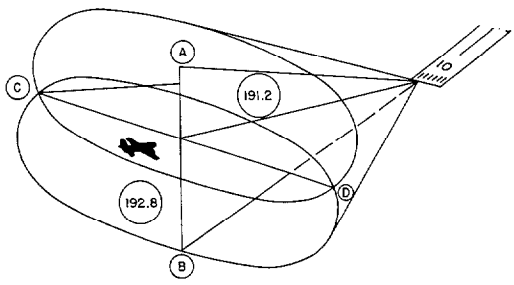

Fig. 2a—Elevation Beam Pattern.

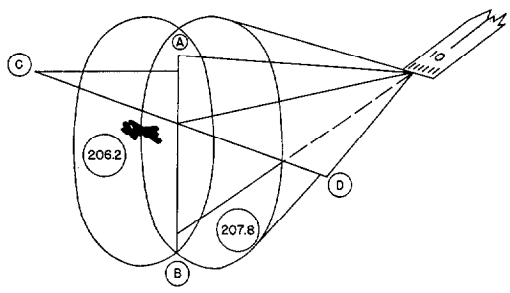

Fig. 2b—Azimuth Beam Pattern.

physical separation of glide slope and localizer equipments, (i.e., split site operation) such that simultaneous localizer and glide beam data can be received in the airborne unit without a loss of integrity.

The radiated microwave guidance signal as observed from an approaching aircraft presents energy levels dependent upon the position of that aircraft with respect to each of the four beams. An aircraft "on course" would observe balanced received amplitudes in glide slope and in localizer beam pairs. The time phased video received signal for an "on course" condition is shown in Fig. 3a.

Since the course line in glide slope and localizer lies on the intersection of two orthogonal planes in which the power in the respective beam pairs is equal, the step scan TALAR system operates in planar coordinates. This can be seen in Fig. 2a and 2b. The localizer plane (AB) of equal power extends throughout the usable azimuth coverage range of $\pm 30°$.

An "off course" condition results in an unbalance in received power in a beam pair or pairs. "Off course" glide slope received signal is shown in Fig. 3b. The "off course" condition in glide slope when processed by the receiver results in a "fly down" indication on a standard ILS indicator. Sense is readily determined by examining

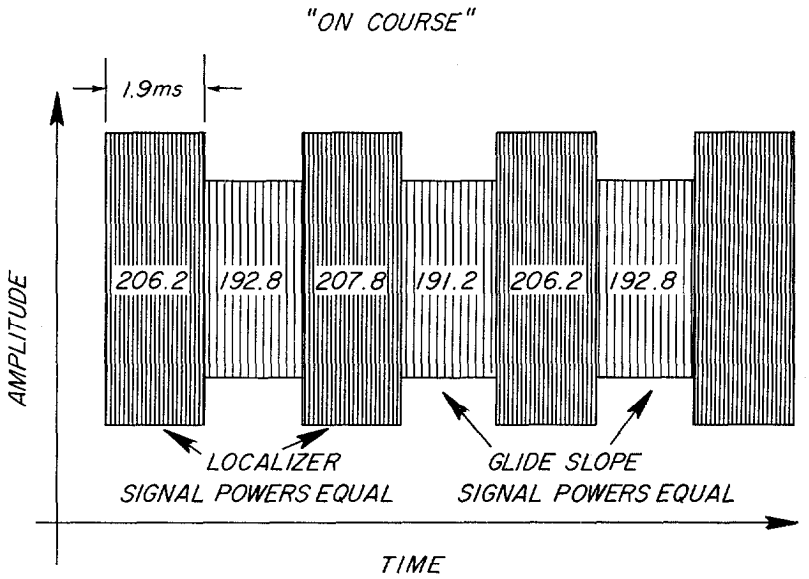

Fig. 3a—Received Step Scan Video Signal.

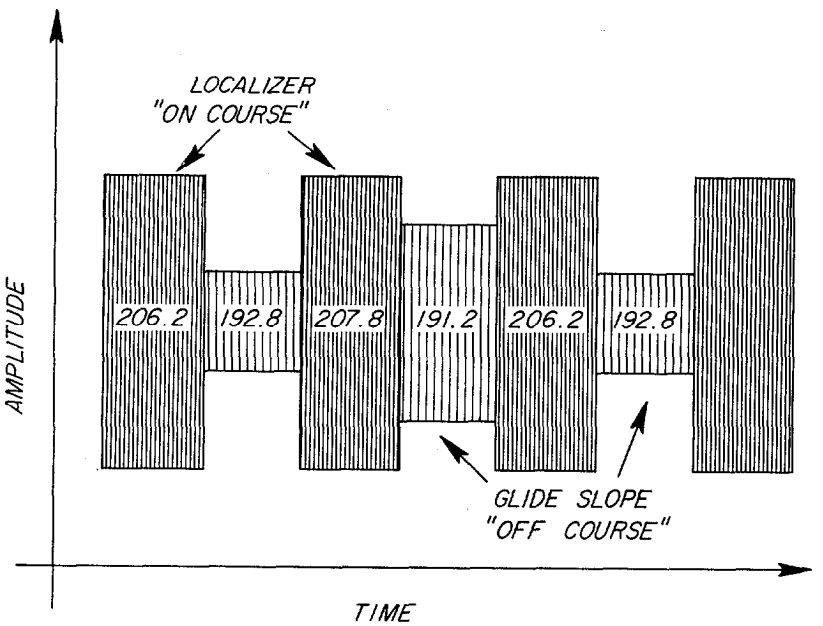

Fig. 3b—Received Step Scan Video Signal.

which of the beam pair subcarrier had the greater signal level. Sense is similarly established in the localizer beam pair. In the case of Gaussian beams, the power variation in db is linear as a function of angular displacement within the limits of the 10 db beamwidth. Thus, the step scan system over the desired course width provides a linear indication of displacement from desired course.

It should be noted that system accuracy is

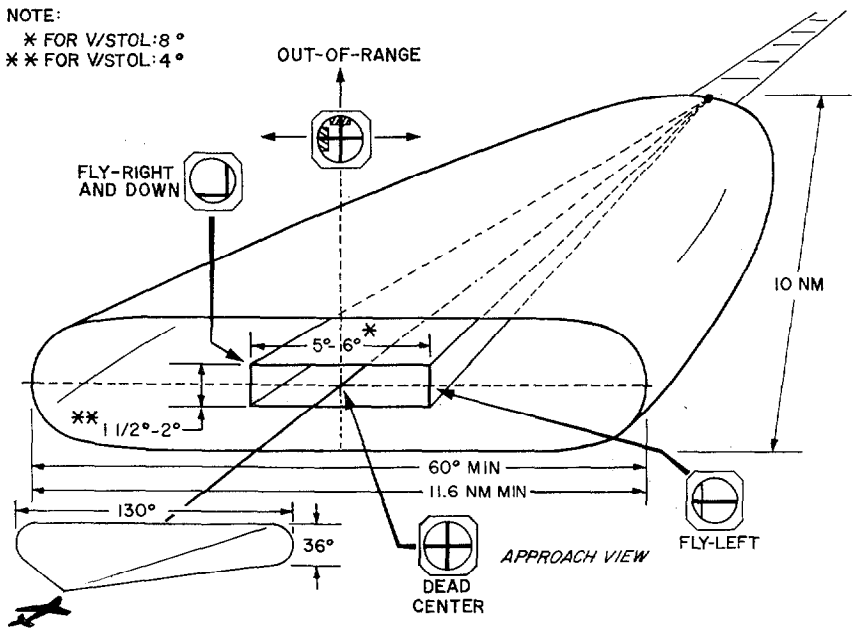

Fig. 4—Course Geometry.

independent of the receiver antenna pattern. Since the ground signals can be considered to radiate from a single point, the energy from the ground intercepts the receiver pattern at one point. An unbalance of the received signal due to the airborne antenna pattern cannot occur.

In addition to the inner or linear portion of operation, it is important that energy also propagate outside the linear region or maximum course width area. This provides the pilot with a broad acquisition window during his initial approach phase. Fig. 4 shows the linear and coverage regions of a typical CTOL TALAR system and the appropriate glide slope localizer indicator positions observed at the various points.

Configurations

The step scan TALAR is a limited coverage scanning beam system. It is similar in many respects to the concepts adopted by RTCA SC-117.[1] The step scan system developments to date at Singer-General Precision are not intended to satisfy the advanced microwave landing requirements since design emphasis has primarily been focused at 200 feet and ½ mile Category I operation. The step scan mechanization, however, does provide a degree of confidence that electronically switched, microwave landing systems do permit multiple, modular interchangeability desired by the RTCA. This has been accomplished by virtue of reduced antenna structure, flexibility in scan rate, scan cycle, encoding, and pattern synthesis. Modular interchange, as will be shown, can transform a base line unit into a variety of configurations that satisfy, in a cost effective manner, the various operational requirements posed by the spectrum of users. The base line unit used by Singer-General Precision from which changes are affected is its portable, tactical, Ku band microwave landing system now in operational use by the USAF.

Fig. 5 is a simplified modular flow diagram that identifies the specific changes necessary to transition operational capability.

In the area of ground equipments, the flow diagram indicates that CTOL (2.75° to 6°) equipments are modified by exchanging CTOL glide slope and localizer antennas with equivalent STOL antennas to provide ground selectable

[1] A New Guidance System for Approach and Landing, Volume One, Document No. DO-148, December 18, 1970

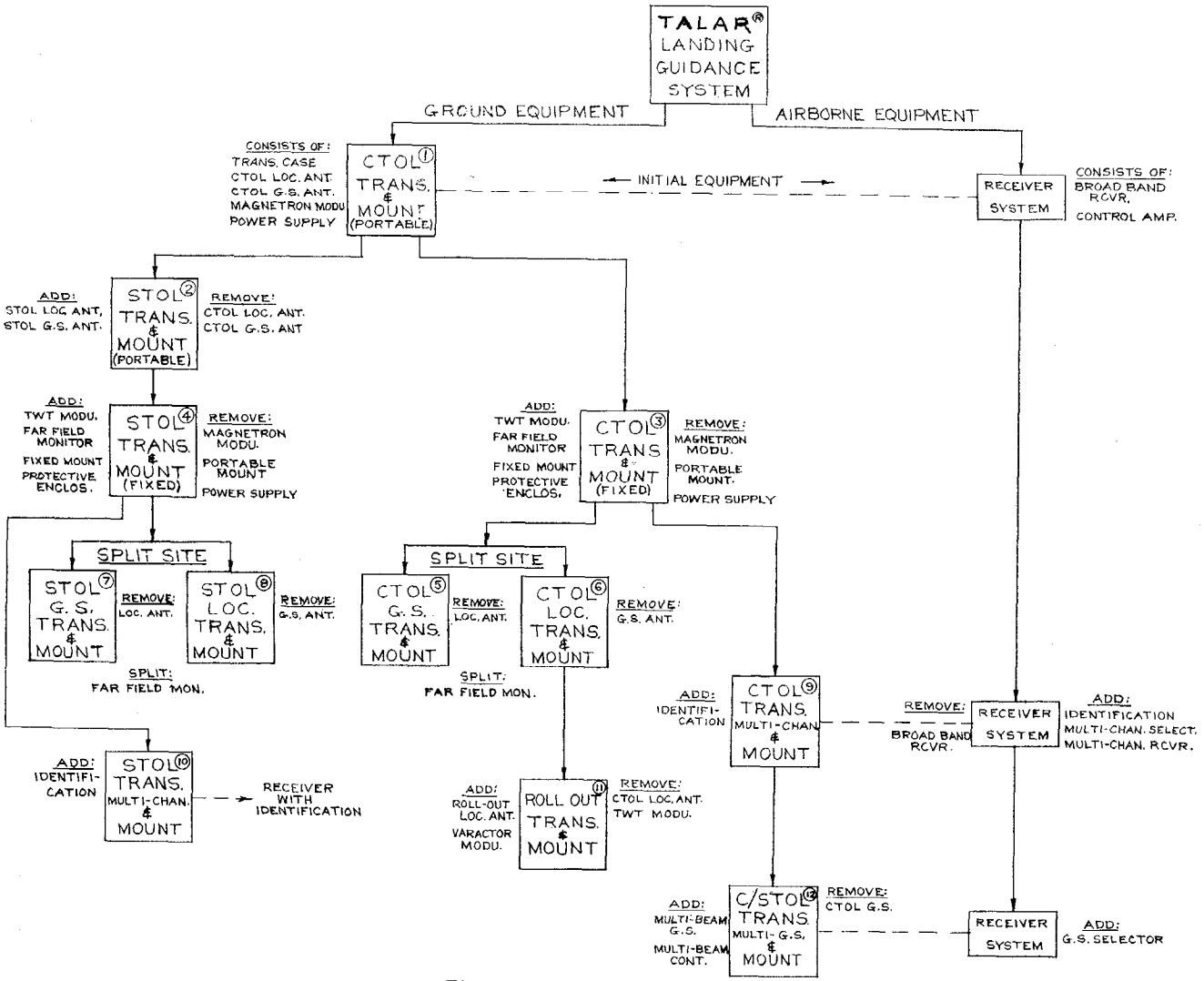

Fig. 5—Modular Flow Diagram.

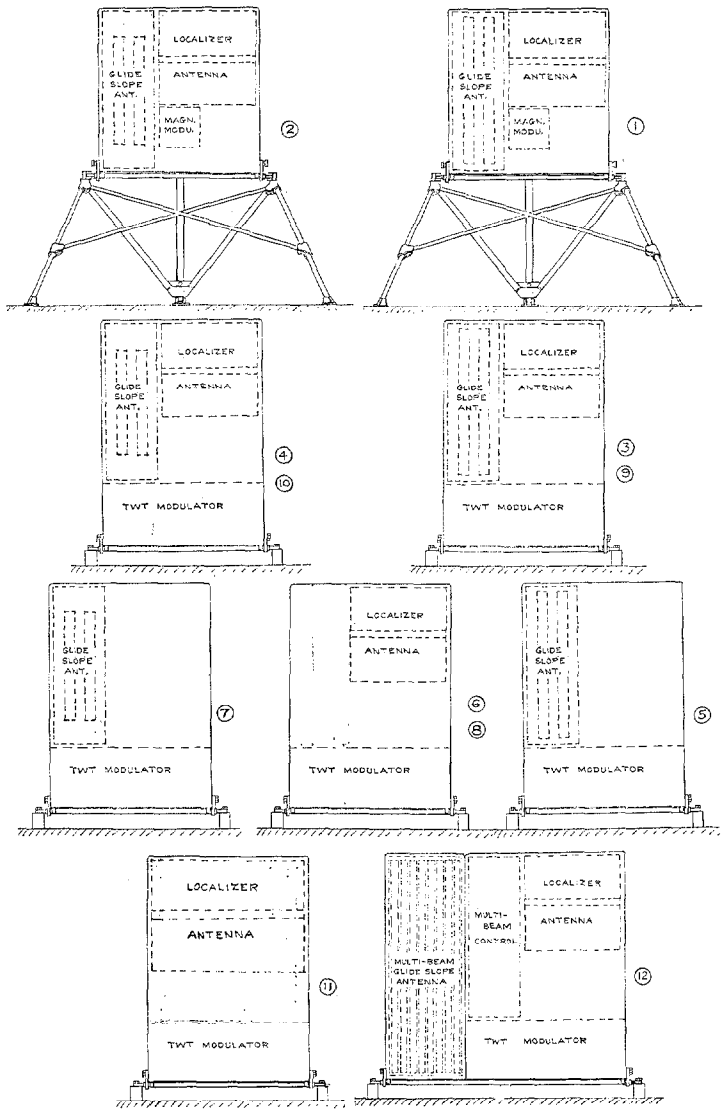

Fig. 6—Various Modular Configurations.

STOL approach paths in the 6° to 9° elevation region. The STOL antennas provide Category I azimuth guidance coverage under the glide path to less than 1° elevation. This accommodates the typical 1000′ to 1500′ level approach prior to intercept of the glide slope by many STOL operators. The STOL antenna patterns have been expanded in azimuth and elevation course width to accommodate the steeper approach paths. TALAR CTOL values of ±2.5° and ±.7° were increased to ±2.7° and ±4.8° respectively. The CTOL unit and the restructured STOL unit are shown in Figs. 6.1 and 6.2.

To provide a fixed base operational capability with either STOL or CTOL units requires the following: An interchange of the lightweight, tactical, magnetron module (10 watt average power magnetron unit) with a solid state driven, long life TWT amplifier module (providing 10 fold increase in operational life for continuous opera-

tion). Interchange of the tactical mount with a frangible fixed mount and the addition of a dual, far field, K band monitor module. The later unit maintains system integrity by monitoring the far field course width, course line, radiated power and station identification. The monitor module provides station shut down and alarm capability when the monitored quantities degrade below ICAO standards. (Figs. 6.3 and 6.4)

Two step scan units configured for STOL operation with far field monitors and equipped with station identification were purchased by FFA in August of 1970 to be used in NAFEC STOL evaluation. Fig. 6.4 is a typical fixed base colocated system of the type supplied to FAA.

To provide simultaneous, multiple ground station operation with signal in space integrity in areas such as Southern California requires the use of contiguous RF channels. This capability has been provided for in the fixed base configuration by making use of the channel selection and narrow band potential of the crystal controlled TWT module. Frequency stability in the order of .003% throughout the environmental range is adequate for this application. Morse code identification is also necessary to confirm that proper airborne selection of the desired ground station has occurred. A station identification module is added to impart Morse code identification on the beam. The identification module frequency shift keys the step scan rate between a nominal 134 Hz and 115 Hz. A shift to 115 Hz scan rate corresponds to a "mark" condition. Scan rate changes in the order of 15% to 25% have not affected the system performance as predicted.

Multi channel operation requires modular changes to the airborne unit as follows:

Replacement of the single channel broad band, TDA RF receiver with a 10 channel superheterodyne receiver operating in the range of 15.450 to 15.550 GHz. This unit contains the conventional K band mixer, local oscillator, 100 MHz IF and video detector subsections. Local oscillator stability is crystal controlled to .003%. Appropriate RF channel selection in the airborne receiver is accomplished by manually selecting a local oscillator frequency. The local oscillator is a phase locked Gunn diode synthesizer. The airborne angle processor monitors the detected video, Fig. 3a and 3b, and generates a 1020 Hz audible tone to the pilot when the 115 Hz scan rate is present.

Runway or rollout guidance is a special requirement, where low angle (virtually horizontal) localizer information is required for runway operation. Aircraft taxiing requires this guidance prior to take off and subsequent to landing. In addition limited coverage above the runway has been necessary for smooth transitional operation during take offs. A runway guidance, step scan unit, has been provided to the USAF for their instrument pilot training evaluation program. This capability is obtained by replacing the CTOL glide slope/localizer antenna modules in the base line unit with a narrow beam localizer only module. Beam coverage is restricted in azimuth to avoid multipath reflections from objects adjacent to the runway. Course width is adjustable to be compatible with various runway lengths (2–15,000) and widths (100′ to 300′). The normal scan cycle which time shares glide slope and localizer information is usually modified to provide continuous localizer information. Power requirements from this application are much reduced, typically 20–50 milliwatts is sufficient.

The configurations discussed above have been produced at Singer-General Precision. Singer is presently developing a multiple angle glide slope unit to become a module in the step scan family and thus provide air selectable glide slope capability. A ground selectable, multi angle engineering model is in the process of modification to permit air selection. The modified module and associated driver module in conjunction with the base line unit will provide planar beam elevation guidance coverage from 2° to 14°. Other than the fact that more than two beams are illuminated beam motion is identical to the conventional CTOL glide slope, i.e., step scan. The additional beams require additional subcarrier codes, i.e., 189.6, 188.0, etc., and additional time slots. This unit is shown in Fig. 6.12.

The basic two module airborne unit is supplemented with a glide slope selector module. The glide slope selector module transforms the received video from the RF receiver into standard glide slope/localizer format required for the normal angle processing unit.

In summary, the TALAR step scan design and operational data supports many of the technical

decisions adopted by RTCA SC-117. Based upon many and varied operational evaluations it is feasible to provide angular guidance utilizing narrow band coding and modulation and maintain channel integrity. It does not appear feasible to expect Ku band performance much beyond 15 miles in rain ½″ to 2″ per hour. It is feasible to configure the ground stations equipped in a modular fashion such that minimal changes are required to optimize ground equipments for the lesser RTCA configurations B, D, E, etc., and more than likely for all configurations.

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